USER GUIDE FOR FLONET AND TRIPLOT

(COMPUTER CODES TO GENERATE HYDROGEOLOGICAL FLOWNETS)

Environment Ontario

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(COMPUTER CODES TO GENERATE

HYDROGEOLOGICAL FLOWNETS)

Technology and Site Assessment Section
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1. INTRODUCTION

Computer models are commonly used by ground-water consultants to provide additional support for their predictions of when , where, and how much contamination will be carried across property boundaries due to contaminated ground water. One example of where ground water models have been extensively used is the submission by the Ontario Waste Management Corporation (OWMC).

The Ministry of Environment (MOE) has a corporate licence permitting the use of several University of Waterloo programs, including FLONET and TRIPLOT. A copy of this licence and the original software has been sent to all MOE hydrogeologists. The objective of this guide is to provide MOE hydrogeologists with a more user - friendly introduction to the basic components of FLONET and TRIPLOT. The guide provides a greater level of assistance for the new user than that provided in the original software documentation. This assistance hopefully allows the new user to more easily construct datafiles and generate plots of flownets for various steady state hydrogeologic crossections.

FLONET is the generic name for the finite element, two-dimensional, steady - state, crossection flow model. The single precision version (FLONT32S.EXE) is less accurate than the double precision version (FLONT32.EXE); however it is quicker and, for simple systems, it enables experimentation with larger grid sizes than can be achieved with FLONT32.

FLONET enables heterogeneous, anisotropic hydrogeologic systems to be modelled since each element of the finite-element grid can be assigned different values for horizontal and vertical permeability and porosity. The boundaries of the

modelled domain can be specified as impermeable, specified head, or specified flux. The grid can be allowed to automatically deform when seeking the new position of the watertable.

TRIPLOT is a contouring program that generates plotfiles of equipotentials and/or streamfunctions produced by FLONT32. These plotfiles can be read by Roland or Hewlett Packard (HP) plotters.

For references and more general details, refer to E. Sudicky's Read.me documentation from the original software package.

The FORTRAN code contains many comments and should be printed out. Of course, the code itself provides the ultimate instructions for datafile format and what the code can do. This guide does not deal with all of the features offered by FLONET. Rather it uses several real datafiles to illustrate, line - by- line, how to compose and generate basic flownets. This detailed information is augmented by comments and hints.

A glossary of terms used in this guide and the original Read.me file is presented in Appendix 1.

A totally revised version of FLONET , called CROSSFLO , has been released by the University of Waterloo in 1988. CROSSFLO has major advantages over FLONET in that it allows the finite element grid to be composed on the screen and does away with the need to create datafiles; however, IBM-type computers cannot run CROSSFLO as it was composed for the ATARI - GEM operating system.

2. SYSTEM REQUIREMENTS

Desirable requirements for the operation of FLONET & TRIPLOT are at least 640 kilobytes (Kb) of random access memory (RAM), a math coprocessor, a hard disk and a Roland or Hewlett Packard (HP) plotter. Roland plotters can use the original version of TRIPLOT whereas HP plotters require the modified version. Both versions have been distributed to MOE users.

Under the DOS disk operating system the RAM can be maximized to roughly 592 Kb by removing any RAM resident programs such as Sidekick or Quick Dos. The text editor used to construct and modify datafiles and the FORTRAN code must be capable of handling large files. For this reason most of the editing for the examples in this guide was done with WordPerfect rather than with Sidekick.

In order to run codes larger than 592 Kb the computing system requires access to more RAM. This can either be done by switching the disk operating system from DOS to OS/2 and extending the RAM to 4-8 Mb or by using an ATARI computer with 1-4 Mb of RAM.

3. COMPOSING A FLONET DATAFILE

3.1 GENERAL

Fig. 1 illustrates the numbering of nodes and elements on a simple finite element grid. In this example the grid is automatically deformed by the code to allow a smooth representation of the watertable. Note that the nodes are always numbered vertically upwards and the elements are numbered horizontally, parallel to the hydrostratigraphy. Numbering the elements parallel to the hydrostratigraphy

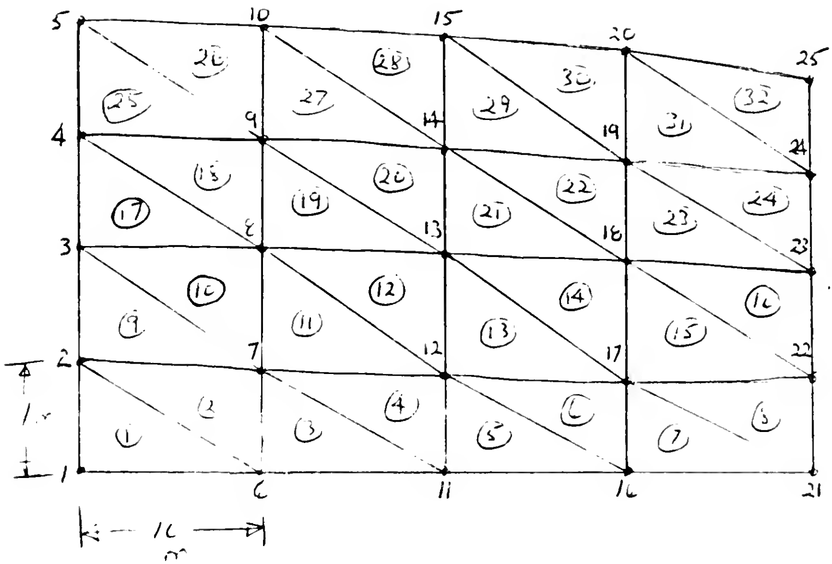
allows the values for hydraulic conductivity and porosity to be easily changed via the "Grouped" method described both below and in the original Read.me file.

Fig.2 illustrates the three boundary conditions (ie, specified head, specified flux and impermeable) that can be applied to a modelled domain. Boundary conditions are entered into the datafile in a clockwise direction starting with the lower left corner.

Any consistent set of units can be used . Metres and years are used in all of the examples in this guide.

FLONET can be run in either the head or streamfunction mode. The head mode generates a head value at each node whereas the streamfunction mode generates a stream function value. Regardless of which mode is chosen there are two methods- the manual and the automatic- that can be used to compose the bulk of the input datafile.

The manual method involves entering data by typing all of the node coordinates and element incidences and is necessary for irregularly shaped domains. An irregular domain can be loosely defined as a domain where the hydrostratigraphy is not parallel to the top boundary. An example of an irregular domain and a regular domain is given in Fig. 5a) and b) respectively.



NUMBER OF NODES(NN) = 25

NUMBER OF ELEMENTS (NE) = 32

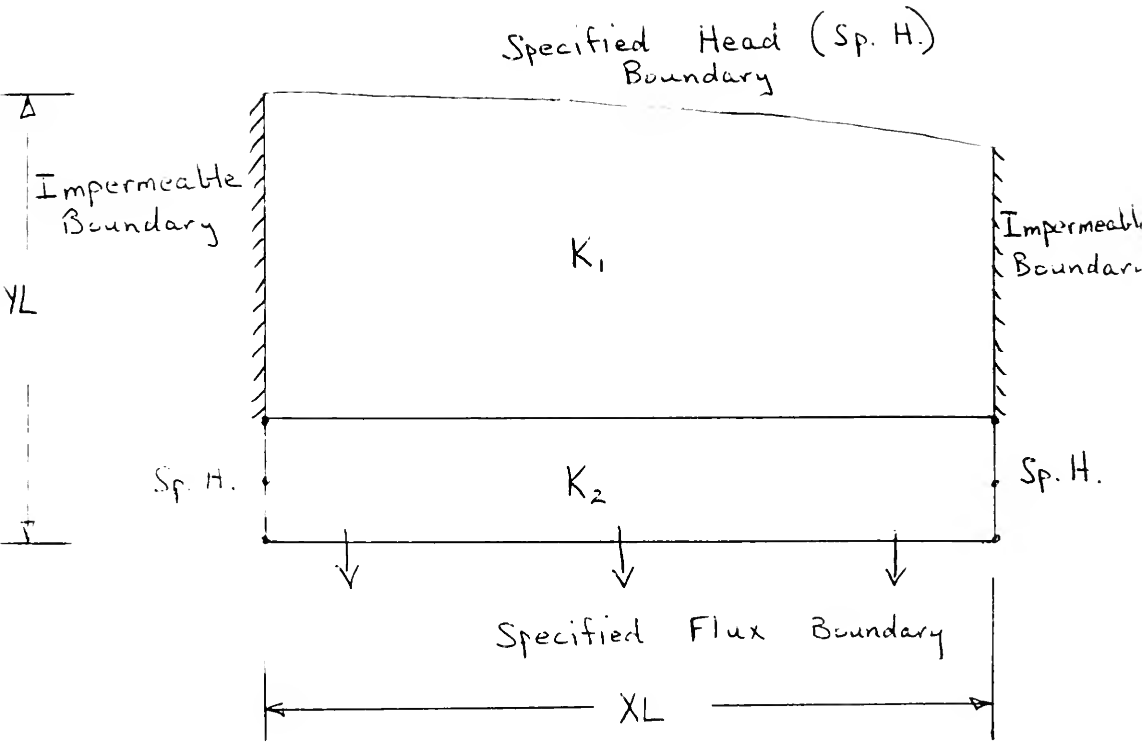
BANDWIDTH (NB) = 6

THE INCIDENCES OF ELEMENT 1 ARE 1,6,2

THE ASPECT RATIO IS 10

A FINITE ELEMENT GRID ILLUSTRATING THE NUMBERING OF NODES AND ELEMENTS

FIG. 1



BOUNDARY CONDITIONS ARE ENTERED CLOCKWISE IN THE DATAFILE STARTING AT THE LOWER LEFT CORNER

ILLUSTRATION OF THE VARIOUS BOUNDARY CONDITIONS

FIG.2

The automatic method allows the computer to enter these data and can be invoked for simple domains. The automatic grid generator method can also be used to quickly perform grid - size sensitivity tests for irregularly shaped domains. This is discussed in more detail in Section 3.3.

The maximum nur[illegible] of nodes and elements in the double precision ver[illegible] [illegible]f FLONET with a 640 Kb system is 1071 and 2000 respectively. Considering this and using a maximum finite element aspect ratio (see Fig. 1) of 100 gives a rule- of- thumb estimate of the maximum size of domain that can be modelled. Other size restrictions, such as maximum number of nodes in the horizontal and vertical directions , are specified in the dimension statements at the beginning of the FORTRAN mainprogram and can be changed if you have a FORTRAN compiler. The recompiled version needs to be small enough to fit into the available RAM.

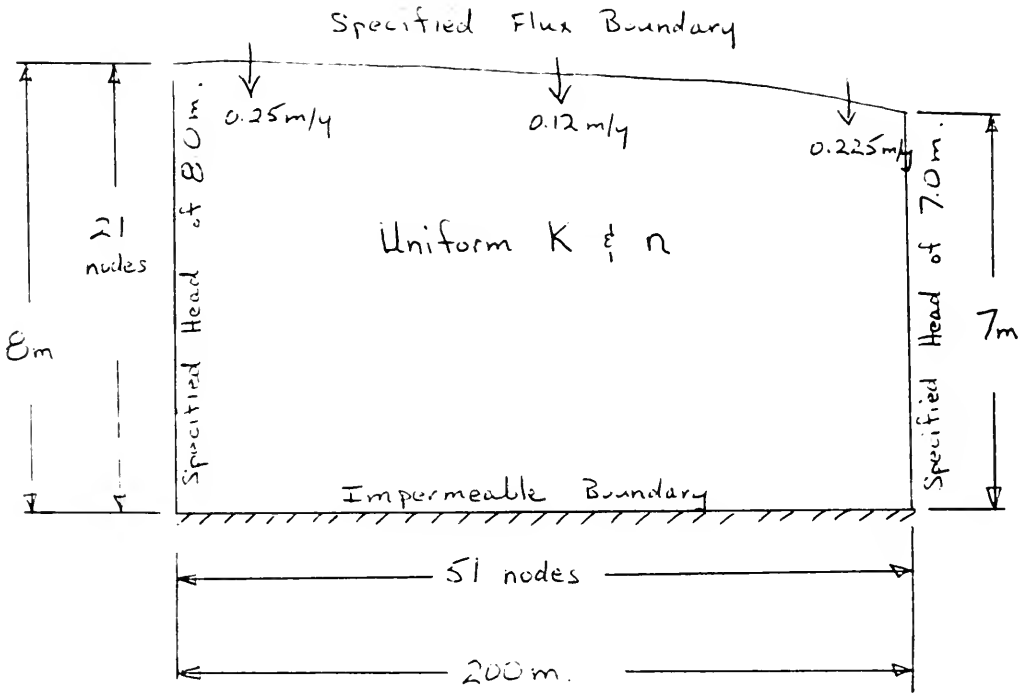
3.2 AUTOMATIC GRID GENERATION

The datafiles provided with the original software package all use the automatic rather than the manual method of entering node coordinates and element incidences. Two of these datafiles will be used here to examine this method of input in more detail. A Glossary of Terms used in this Guide is provided in Table 1.

It is important to realize that in the autogrid method the Y coordinates along the bottom are assigned an elevation of zero by the code. Therefore if the heads are given in metres AMSL they have to be recalculated so that they are correct relative to the zero elevation along the base.

3.21 POTENTIAL OR HEAD MODE - AUTOMATIC GRID

The following datafile, Flonetp.dat, is from the original software package, and is used for solving for the unknown heads at each node. The datafile has been modified to identify what each line of input represents. The real datafile would have no spaces between lines. It is recommended that a sketch of the modelled domain be made so that it and the boundary conditions can be easily recalled. Such a sketch for Flonetp.dat is shown in Fig. 3



NN = 1071

NE = 2000

NC = 42 = 21 NODES ON EACH VERTICAL SIDE

NF = 51= TOP BOUNDARY

SCHEMATIC OF CONDITIONS FOR FLONETP.DAT

FIG. 3

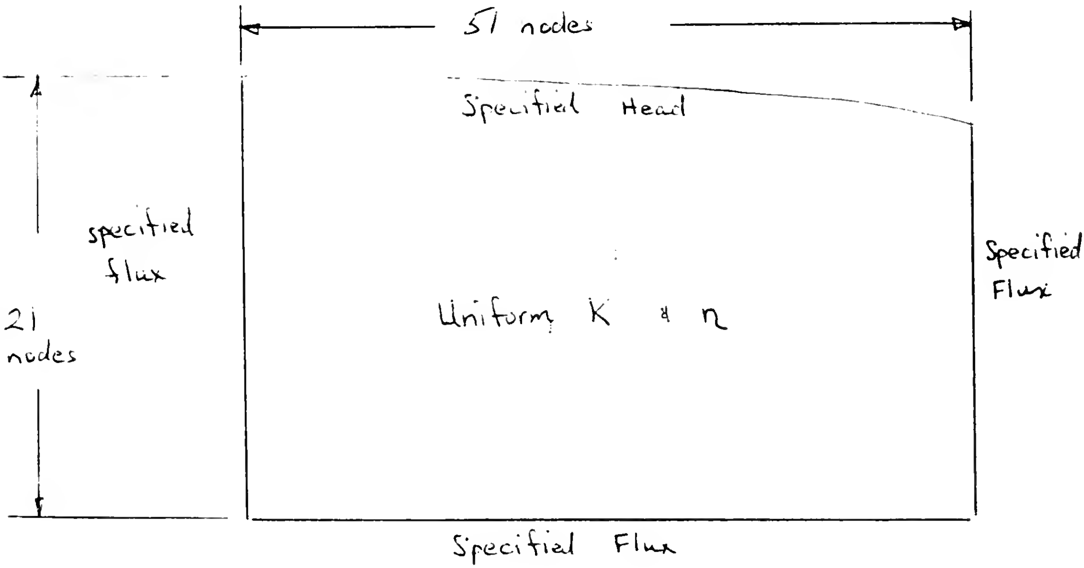
```
Flonetp.dat
CASE 1: SEEKING WATERTABLE ;title
P                          ;code for potential mode
TRI                        ;code for triangular elements
GEN                        ;code to autogenerate grid
21,51,8,200,-1             ;NV,NH,YL,XL,SLOPE

42,22,51                   ;NC,NB,NF; corner nodes are counted
                           twice
0,0                        ;NIC,NIF; there are no internal
                           specified head or flux nodes
NON                        ;code for nonrectangular grid
SEE                        ;code for seeking watertable
1                          ;all nodes above this can relax when
                           grid deforms to seek watertable
H                          ;code for Head Boundary To Follow.
                           Note that boundaries are read
                           clockwise, starting at the lower left
1,21,8.0                   ;nodes 1 through 21 have head of 8.0m
Q                          ;code for Flux Boundary To Follow
21,378,0.25                ;nodes 21 through 378 along the top
                           boundary have a Darcy flux of 0.25m/y
378,693,0.12               ;nodes 378-693 have Darcy flux=0.12m/y
693,1071,0.225             ;nodes693-1071 have Darcy flux=0.225
H                          ;code for Head Boundary To Follow
1071,1051,7.0              ;nodes 1071-1051 on RHS have head=7.0m
Z                          ;code for Impermeable Boundary.
                           Nothing needs to be specified.
GRO                        ;code for Grouped K data to follow
1,2000,1576.8,1576.8,0.0   ;elements 1-2000 have Kx&Ky=1576.8m/y
                           The angle of the principal direction of
                           the permeability to the grid axis is  0.
                           degrees.
```

GRO	;code for Grouped porositydatatofollow
1,2000,0.35	;elements 1-2000 have n= 0.35
YES	;code for printout of listing file
'FLONETP.LST'	; name of listing file in quotes
NO	; code for not including input data in listing file. This should be 'yes' for initial runs to check input is correct.
NO	; code for not making a file for the mesh data(node coordinates element incidences). This needs to be 'yes' to use TRIPLOT
YES	;code for writing height of watertable above YL to disk.
'FLONET.WT'	; name of above watertable file
YES	;code for sending nodal output to disk
'FLONETP.OUT'	;name of above output file. This is contoured by TRIPLOT
YES	;code for calculating velocities
YES	; code for sending velocities to disk
'FLONETP.VEL'	; name of above output file
YES	; code for calculating flux at dirichlet nodes and including them in the listing file. This is necessary to determine fluxes into and out of the domain.

3.22 STREAMFUNCTION MODE

The following annotated streamfunction datafile ,Flonets.dat, is also from the original software package.Only new aspects of the datafile are commented on . See Flonetp.dat for the basic set of comments on the general aspects of input datafiles.
Fig 4 is a sketch of the modelled domain for Flonets.dat illustrating the pertinent features.



SCHEMATIC OF CONDITIONS FOR FLONETS.DAT

FIG. 4

FLONETS.DAT

```
TEST CASE FOR STREAMFUNCTIONS - CASE 1
S                             ;code for streamfunction mode
TRI
GEN
21,51,8,200,-1
51,22,91                      ; LINE 6-NC,NB,NF; See Fig.4  and
                              comments following datafile
0,0
NON                           ;code for nonrectangular grid
WAT                           ; code for watertable heads above YL
                              will be read from existing file on
                              disk
1                             ;code for all nodes to relax
'FLONET.WT'                   ; filename for watertable head info
H                             ; LINE 12-lefthand boundary condition
remains                       labelled as specified head
1,21,8.0                      ;same input as for potential datafile
                              See comments following datafile.
H                             ;top boundary(watertable) is inserted
                              as a specified head boundary but
                              head values are read in'flonet.wt'
                              above rather than here.

H                             ;righthand boundary remains specified
                              as specified head boundary
1071,1051,7.0                 ;LINE 16
Z                             ;bottom boundary continues to be
1051,1,0.0    - LINE 18-      labelled as  impermeable
                              but  all of the nodes have a
                              specified flux value of 0.0m/y .
                              See comments following datafile.
```

```
GRO                               ;GROUPED ELEMENT K DATA
1,2000,1576.8,1576.8,0.0
GRO                               ;GROUPED ELEMENT POROSITY DATA
1,2000,0.35
YES                               ;YES FOR A PRINTOUT
'FLONETS.LST'
NO                                ;NO FOR PRINTING INPUT DATA
NO                                ;NO FOR SENDING MESH DATA TO DISK
NO                                ; NO FOR SENDING HEIGHT OF
                                  WATERTABLE ABOVE YL TO DISK
YES                               ;YES FOR SENDING NODAL OUTPUT TO
                                  DISK.
'FLONETS.OUT'
YES                               ;YES FOR CALCULATING VELOCITIES
YES                               ;YES FOR SENDING VELOCITIES TO
                                   DISK
'FLONETS.VEL'
```

The values entered for NC and NF in line 6 of the input datafile for the streamfunction mode are different than for the potential mode in that specified head nodes from FLONETP.DAT are now counted as NF nodes in FLONETS.DAT and, conversely, specified flux nodes from FLONETP.DAT are counted as NC nodes in FLONTS.DAT. Therefore, since the specified flux boundary for the top boundary of the potential mode has been entered in Flonets.dat as a specified head (watertable) file, the top boundary nodes are included with those on the two sides to make a total of 91 NF nodes. Corner nodes are not counted twice. The impermeable bottom boundary however, which by definition has a specified flux of zero , becomes a collection of 51 NC nodes.

It should be noted that, when using the automatic grid method, the code automatically computes the appropriate flux input when specifying the head boundary conditions in lines 12-16. The computed fluxes can be inspected in the listing file. In other words, although cumulative fluxes around the borders of the domain are necessary to define the boundary conditions for the streamfunction version, heads can be directly used as input in the automatic option.

As shown in line 18, the cumulative flux along the lower impermeable boundary (Z) has been entered as 0.0 m/y. This is because the bottom boundary is the Reference Streamline where the Reference Streamline is that which has the minimum flux in the domain. The cumulative flux in the domain starts at 0.0 m/y at the lower left corner ,builds to a maximum around the domain and , because the bottom is impermeable, declines to 0.0 again at the lower right corner .

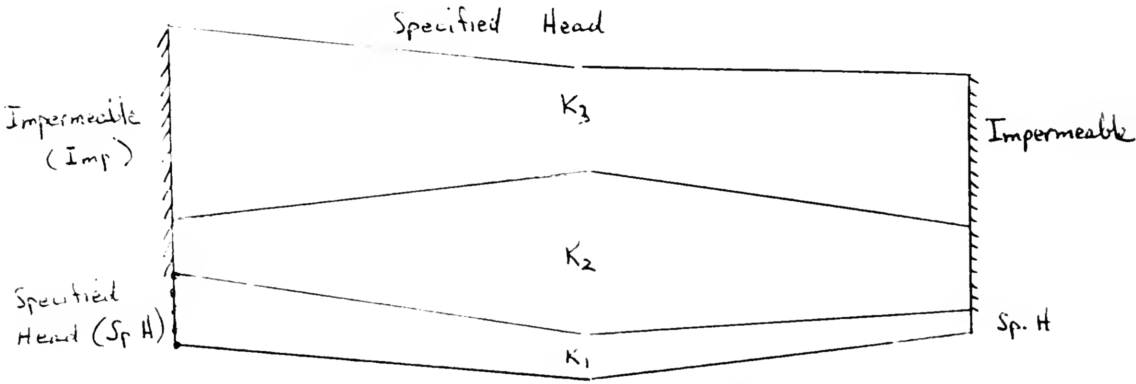
3.3 OTHER USES FOR AUTOMATIC METHOD

3.31 GRID SIZE SENSITIVITY

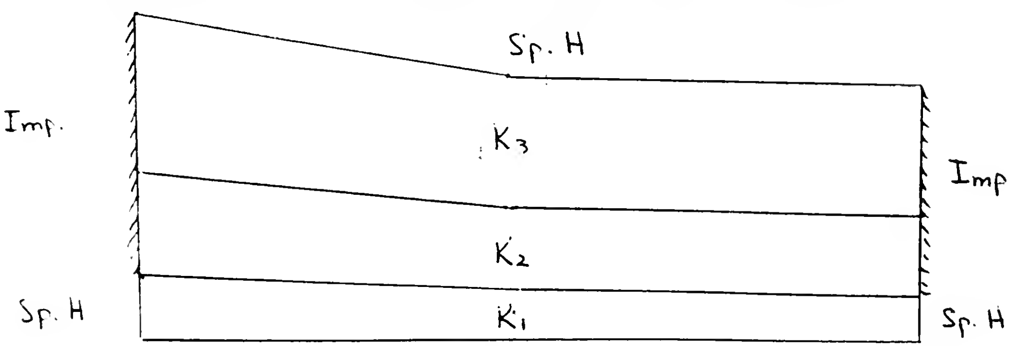
Fig. 5 shows how an irregular domain that requires manual input of node coordinates and element incidences can be simplified so that autogrid versions can be run and grid- size sensitivity easily determined. Note that the only difference is the geometry of the hydrostratigraphy.

It is important to realize that in the autogrid method the Y coordinates along the bottom are assigned an elevation of zero by the code. Therefore if the heads are given in metres AMSL they have to be recalculated so that they are correct relative to the zero elevation along the base.

Also, the automatic method can only handle a watertable- type top boundary (ie. head = elevation). Further, the code requires that the heads be entered so that they are equal to the " Height of watertable above YL", where YL is the height of the domain on the left hand side. Therefore, in Fig.5, the heads on the top boundary have to be altered so that the head at the top left corner equals its elevation and the height of the watertable above YL equals zero. This is done by subtracting the head value of the top left node from each node on the top boundary .



5A -IRREGULAR DOMAIN THAT REQUIRES MANUAL INPUT OF GRID DATA



5B - DOMAIN IN 5A ALTERED SO THAT AUTOMATIC GRID GENERATOR CAN BE USED

MODIFICATION OF AN IRREGULAR GRID TO ALLOW USE OF AUTOMATIC GRID GENERATOR

FIG. 5

Although the resulting heads will not be correct for the modelled cross section, remember that the purpose of this exercise is grid-size sensitivity and not correct heads. SUBTRACT.EXE can quickly do this subtraction and put the data in the correct format by including a counter. This newly created datafile can then be pasted into the main datafile using the "list files" feature of WordPerfect.

When performing grid- size sensitivity tests ,SUBDUBLE.EXE and NUMBER.EXE are two utilities that can be used to halve the aspect ratio by increasing the number of nodes on the top boundary and to generate the correct data format without typing in the head values directly.

If the results from the two automatic runs with different aspect ratios are not the same then further testing is necessary to see when the results converge. If the results are consistent then you can choose to decrease the number of nodes and test for convergence again. You may wish to choose the grid with least number of nodes when the manual- input method is chosen since that method is relatively time consuming.

A description of SUBTRACT.EXE and other utilities used in this guide is presented in 4.0

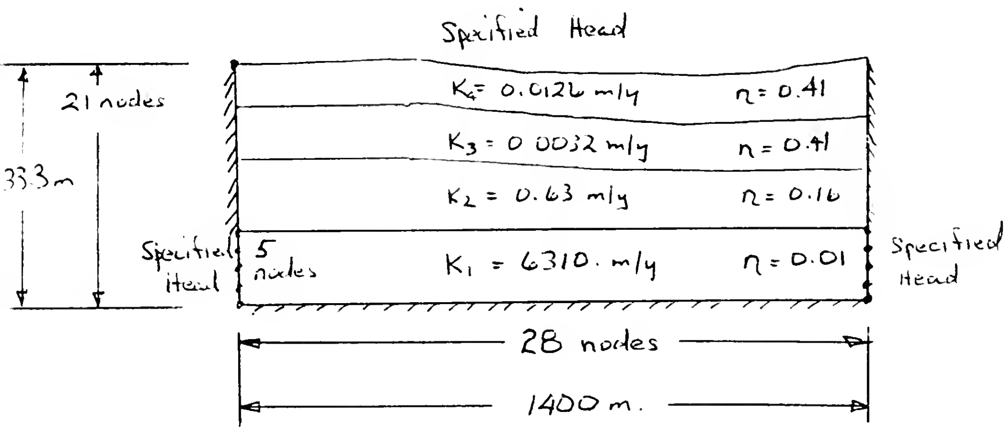
3.32 GENERATING NODE COORDINATES AND ELEMENT INCIDENCES FOR MANUAL METHOD

The automatic method can also be used to advantage even when the node coordinates and element incidences need to be read directly from the datafile rather than autogenerated. For example, this would be necessary in order to have a head top boundary that is not a watertable. If layer -cake hydrogeology can be assumed then the

autogrid feature can be used to generate the coordinates and incidences in the listing file. Pasting these portions from the listing file into the main datafile is easily accomplished with the utility SELECT.EXE and "Block and Move" features of WordPerfect.

It is important to note that when the left side is partially a specified head boundary eg.Fig.5 or 6 (Boundary code H) and there is an impermeable boundary along some portion of it at the top, the head at the top left corner needs to be specified even though that node is impermeable. If this is not done an error message will result and the program will not run.

An example of an autogrid datafile that has these features, including producing information in the listing file that can be pasted in the main "manual input" datafile, is provided below.



SCHEMATIC OF AUTO2. DOMAIN

FIG. 6

```
AUTO2- DEEP SYSTEM- REGULAR GRID      ; title
P
TRI
GEN
21,28,33.3,1400,-1
39,22,0
0,0
NON
REA                              ;code for reading the watertable
1
    1           .00000     ;counter and modified head so that
    2           .00000      value is = height of watertable above
    3           .00000      YL. Use SUBTRACT.EXE to do this.
    4           .00000
    5           .00000
    6           .00000
    7           .00000
    8           .00000
    9           .00000
   10          -.15001
   11          -.31001
   12          -.46001
   13          -.61000
   14          -.76001
   15          -.92001
   16         -1.07001
   17         -1.11000
   18         -1.14000
   19         -1.18001
   20         -1.21001
   21         -1.25000
   22         -1.29001
   23         -1.32001
```

```
   24          -1.36000
   25          -1.39000
   26          -1.43001
   27          -1.46001
   28          -1.50000
H                                ;Left boundary contains specified heads
1,5,176.21                       ;nodes 1-5 are specified; rest are
                                 impermeable
21,21,183.1                      ;top node is specified even though its
                                 impermeable. See comments preceding
                                 this datafile
H                                ; top boundary- nothing is read here
H                                ;Right boundary contains specified
                                 heads
572,568,175.92                   ;top impermeable node does not need to
                                 be specified
Z

GRO                              ; Grouped K data
1,216,6310.0,6310.0,0.0
217,432,.631,.631,0.0
433,756,.0032,.0032,0.0
757,1080,.0126,.0126,0.0
GRO                               ; Grouped porosity data
1,216,.01
217,432,.16
433,1080,.41
YES
'AUTO2.LST'
YES
YES
'AUTO2.ESH'
NO
YES
```

'AUTO2.OUT'

YES

YES

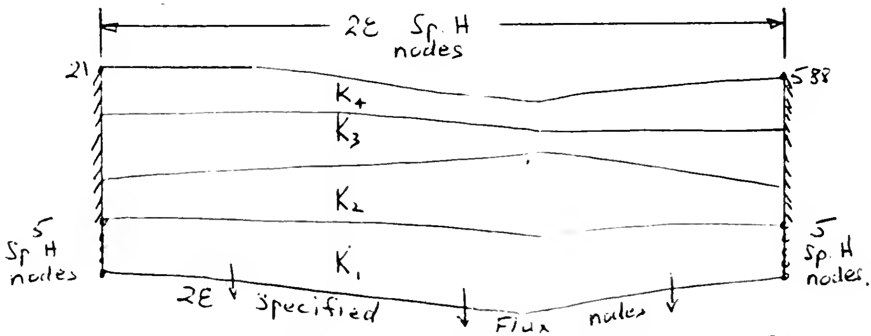
'AUTO2.VEL'

YES

3.4 MANUAL INPUT METHOD - MAKING YOUR OWN GRID

3.41 SETTING UP A POTENTIAL DATAFILE

The following datafile is for the potential mode of the irregular domain illustrated in Fig. 5a). All information necessary to describe the domain is included.To minimize repetition only the new aspects in the datafile are commented on. The utilities mentioned in the commentary can be used to automate some of the input and are described in 4.0. There is however no alternative to manually drawing the grid and typing in the nodes and coordinates in FLONET. Guidance for element sizing would come from an autogrid exercise of the type described in Section 3.31



NN = 588; NE = 1080; NC = 5+28+5 = 38, ND = 22; NF = 28

SCHEMATIC OF DEEP SYSTEM DOMAIN (POTENTIALS)

FIG. 7

```
DEEP SYSTEM WITH FLUX BOTTOM BOUNDARY
P
TRI
REA                     ; read the grid information rather than
                        automatically generating it
588,1080                ;NN,NE
38,22,28                ;NC,NB,NF ;See Fig.7
1,0.0,146.0             ;counter, X coord., Y coord.
2,0.0,147.5             starting at lower left and always
3,0.0,148.9             moving upwards
4,0.0,150.0
5,0.0,151.5
6,0.0,152.0
7,0.0,152.5
8,0.0,153.0
9,0.0,153.5
10,0.0,155.1
11,0.0,157.1
12,0.0,159.0
13,0.0,160.5
14,0.0,162.3
15,0.0,164.1
16,0.0,166.5
17,0.0,169.0
18,0.0,171.1
19,0.0,173.5
20,0.0,176.0
21,0.0,178.1
22,50.0,146.0
23,50.0,147.5
24,50.0,148.9
   1,   1,  22,   2   ;element number, element incidences
   2,  22,  23,   2    This part of the file can be generated
                       either by using SELECT.EXE with the
```

```
                              listing file of an autogrid run or by
                              using INCIDENZ.EXE  if no autogrid run was
                              done for grid-size sensitivity.
   3,  22,  43,  23
   4,  43,  44,  23
   5,  43,  64,  44
   6,  64,  65,  44
   7,  64,  85,  65
   8,  85,  86,  65
   9,  85, 106,  86
  10, 106, 107,  86
  11, 106, 127, 107
  12, 127, 128, 107
  13, 127, 148, 128
  14, 148, 149, 128
  15, 148, 169, 149
  16, 169, 170, 149
1073, 503, 524, 504
1074, 524, 525, 504
1075, 524, 545, 525
1076, 545, 546, 525
1077, 545, 566, 546
1078, 566, 567, 546
1079, 566, 587, 567
1080, 587, 588, 567
1,176.21          ;Left Boundary: node number,specified head value
2,176.21           for nodes 1-5. Rest are omitted since they are
3,176.21           impermeable. Note that the boundary codes H,Q,Z
4,176.21           are not used in the "read"  version of FLONT32.
5,176.21
21,183.6          ;Top Boundary: node number , specified head.
42,183.6           These values can be pasted in from the previous
                   autogrid run using the " block" and "append"
                   features of WordPerfect
```

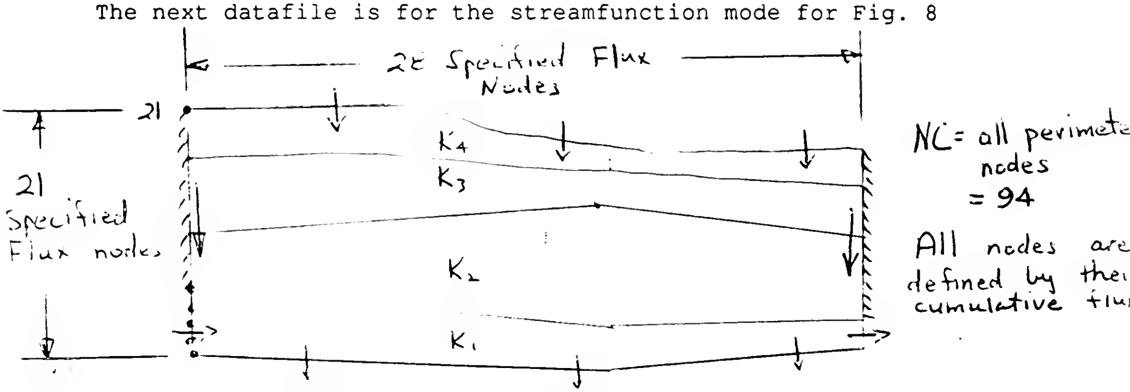
```
63,183.6
84,183.6
105,183.6
126,183.6
147,183.6
168,183.6
189,183.6
210,183.45
231,183.29
252,183.14
273,182.99
294,182.84
315,182.68
336,182.53
357,182.49
378,182.46
399,182.42
420,182.39
441,182.35
462,182.31
483,182.28
504,182.24
525,182.21
546,182.17
567,182.14
588,182.1
572,175.92      ;Right Boundary: node number and specified head
571,175.92
570,175.92
569,175.92
568,175.92
1,568,-.08      ;Bottom Boundary: counter, node number, nodal
                flux.(Negative flux is that leaving the domain)
```

```
2,547,-.42        This portion of the input was constructed using
                  FLUX.EXE
3,526,-.42
4,505,-.42
5,484,-.42
6,463,-.42
7,442,-.42
8,421,-.42
9,400,-.42
10,379,-.42
11,358,-.42
12,337,-.42
13,316,-.42
14,295,-.42
15,274,-.42
16,253,-.42
17,232,-.42
18,211,-.42
19,190,-.42
20,169,-.42
21,148,-.42
22,127,-.42
23,106,-.42
24,85,-.42
25,64,-.42
26,43,-.42
27,22,-.42
28,1,-.21          ; nodal flux is half the previous value since
                   there is only one side to a corner node
GRO                ; Group K data and rest of file is the
                   same as for the autogen datafile and
                   therefore can be pasted in here.
1,216,6310.0,6310.0,0.0
217,432,.631,.631,0.0
```

```
433,756,.0032,.0032,0.0
757,1080,.0126,.0126,0.0
GRO
1,216,.01
217,432,.16
433,1080,.41
YES
'DEEP1.LST'
YES
YES
'DEEP1.ESH'
NO
YES
'DEEP1.OUT'
YES
YES
'DEEP1.VEL'
YES
```

3.42 SETTING UP A STREAMFUNCTION DATAFILE

The next datafile is for the streamfunction mode for Fig. 8



SCHEMATIC OF DEEP SYSTEM DOMAIN (STREAMFUNCTIONS)

FIG. 8

```
DEEP SYSTEM WITH FLUX LOWER BOUNDARY
S                ; streamfunction mode
TRI
REA             ;read grid information
588,1080        ;NN,NE
94,22,0         ;NC,NB,NF; see Fig 8 above to see how nodes are
                identified and Section 3.22.If all the boundaries
                are specified flux then NC= the number of perimeter
                nodes.
1,0.0,146.0     ; node number and coord.
2,0.0,147.5
3,0.0,148.9
4,0.0,150.0
5,0.0,151.5
6,0.0,152.0
7,0.0,152.5
1075, 524, 545, 525  ; element number and incidences
1076, 545, 546, 525
1077, 545, 566, 546
1078, 566, 567, 546
1079, 566, 587, 567
1080, 587, 588, 567
1,  0.0             ;node and cumulative flux at that node.
2,  2.864825        Cumulative nodal flux determined by using
                    FLUX.EXE
3,  5.486430        on the flux output  for Dirichlet nodes in
                    the listing file for the potential version
4,  7.962015
5, 10.638540        The flux remains constant along impermeable
                    boundaries. Input facilitated by FLUX2.EXE
6, 10.63854
7, 10.63854
8, 10.63854
9, 10.63854
```

```
10, 10.63854
11, 10.63854
12,10.63854
13, 10.63854
14, 10.63854
15, 10.63854
16, 10.63854
17,10.63854
18,10.63854
19,10.63854
20, 10.63854
21,10.63854         ;Top Boundary:
   42, 10.724140    Flux input facilitated by using FLUX.EXE
   63, 10.811990
   84, 10.897020
  105, 10.980200
  126, 11.063570
  147, 11.143820
  168, 11.221130
  189, 11.292470
  210, 11.365250
  231, 11.447170
  252, 11.526100
  273, 11.603180
  294, 11.686520
  315, 11.769160
  336, 11.844620
  357, 11.919200
  378, 11.997430
  399, 12.072420
  420, 12.143390
  441, 12.214840
  462, 12.287990
  483, 12.361310
```

```
504, 12.430140
525, 12.499580
546, 12.574520
567, 12.635390

588, 12.664650     ;Right Boundary: Flux values are constant
                    along impermeable boundaries
587, 12.664650
586, 12.664650
585, 12.664650
584, 12.664650
583, 12.664650
582, 12.664650
581, 12.664650
580, 12.664650
579, 12.664650
578, 12.664650
577, 12.664650
576, 12.664650
575, 12.664650
574, 12.664650
573, 12.664650
572, 12.664650
571, 12.267970
570, 11.863460
569, 11.429140
568, 10.920000    ;Bottom Boundary: cumulative flux decreases
                   at a constant rate specified in the flux
                   boundary in the potential version so that
                   cumulative flux returns to 0.0 at node 1.
547, 10.500000     Use FLUX3.EXE to speed data input.
526, 10.080000
505,  9.660000
484,  9.240000
```

```
  463,  8.820000
  442,  8.400000
  421,  7.980000
  400,  7.559999
  379,  7.139999
  358,  6.719999
  337,  6.299999
  316,  5.879999
  295,  5.459999
  274,  5.039999
  253,  4.619999
  232,  4.199999
  211,  3.779999
  190,  3.359999
  169,  2.939999
  148,  2.519999
  127,  2.099998
  106,  1.679999
   85,  1.259999
   64,   .839999
   43,   .419999
   22,   .000001
GRO
1,216,6310.0,6310.0,0.0
217,432,.631,.631,0.0
433,756,.0032,.0032,0.0
757,1080,.0126,.0126,0.0
GRO
1,216,.01
217,432,.16
433,1080,.41
YES
'DEEP1S.LST'
YES
```

NO

NO

YES

'DEEP1S.OUT'

YES

YES

'DEEP1S.VEL'

YES

4. DESCRIPTION OF UTILITIES

This section describes the various utilities (ie. small programs that generate part of an input datafile) referred to in this guide. The descriptions given here are mostly the READ.ME documentation files associated with each utility. Most of the codes use elementary FORTRAN and therefore may be easily changed to perform new or similar tasks.

4.1 ADD.EXE

ADD.EXE ADDS UP THE FLUXES ALONG ANY PART OF ANY BOUNDARY AND IS USEFUL IN DETERMINING TOTAL FLUX ENTERING OR LEAVING A HYDROGEOLOGIC UNIT.

HOW TO USE ADD.EXE :

1. TO MAKE THE INPUT FILE FOR ADD.EXE, FIRST CREATE AN EMPTY FILE. RETURN TO FILE CONTAINING THE TERMS TO BE ADDED AND BLOCK THEM OUT. APPEND THE BLOCKED LINES TO THE EMPTY FILE USING THE APPEND FEATURE OF WORDPERFECT.

2. PUT THE NUMBER OF SEGMENTS TO BE ADDED IN THE FIRST LINE AND THE NUMBER OF TERMS IN EACH SEGMENT IN THE NEXT LINES. FOR EXAMPLE:

```
3       ;NUMBER OF SEGMENTS TO BE ADDED
5       ;NUMBER OF TERMS IN THE FIRST SEGMENT
```

```
                    28      ;NUMBER OF TERMS IN SECOND SEGMENT
                    5       ;NUMBER OF TERMS IN THE THIRD SEGMENT
NODE NUMBER     FLUX VALUE  ;TERMS TO BE ADDED
     .                .
     .                .
     .                .
```

3. WHEN YOU RUN ADD.EXE YOU WILL SEE TWO QUESTIONS: ONE ASKING FOR THE NAME OF THE INPUT DATA , AND ONE FOR THE NAME OF THE OUTPUT FILE. THE OUTPUT FILE CONTAINS THE SAME INFORMATION AS THE SCREEN.

ATTENTION:

WHEN YOU WANT TO CALCULATE THE TOTAL FLUX FOR A GROUP OF NODES ALONG THE TOP BOUNDARY, WATCH THE LAST ONE BECAUSE IT MAY NOT BE PROPERLY LOCATED FOR ADD.EXE. FOR EXAMPLE, FOR THE WATERTABLE ,THE LAST NODE NEEDS TO BE MOVED FROM THE END OF THE FILE TO ITS PROPER LOCATION WITH THE OTHER WATERTABLE NODES. THIS IS BECAUSE IN THE .LST FILE THE FLUX NODES ARE LISTED IN INCREASING ORDER.

4.2 FLUX.EXE

FLUX.EXE PRODUCES INPUT FOR THE STREAMFUNCTION VERSION OF FLONET BY DETERMINING THE CUMULATIVE NODAL FLUX FOR A SERIES OF NODES.

COPY NODE NUMBERS AND FLUX VALUES FROM POTENTIAL LISTING TO A NEW FILE AND ENTER NUMBER OF NODES AND INITIAL CUMULATIVE FLUX IN LINES 1 AND 2 AT THE TOP OF THE DATAFILE. OUTPUT IS APPENDED TO STREAMFUNCTION DATAFILE AND THEN MOVED TO APPROPRIATE POSITION. USE FLUX2.EXE TO HANDLE CONSTANT FLUX BOUNDARIES.

4.3 FLUX2.EXE

FLUX2.EXE PRODUCES THE CORRECT FORMAT FOR THE STREAMFUNCTION VERSION OF FLONET FOR A BOTTOM FLUX BOUNDARY WITH A CONSTANT RATE OF CUMULATIVE FLUX CHANGE . THE INPUT FILE CONSISTS OF ONLY ONE LINE AS FOLLOWS:

LRNN,NN,NC,FLUX,FLUX1

WHERE LRNN= lower right node number

NV= number vertical nodes

NC= #columns of nodes

FLUX= flux increment between nodes (-ve is negative increment)

FLUX1= initial cumulative flux at lrnn

4.4 FLUX3.EXE

FLUX3.EXE GENERATES NODES AND CONSTANT FLUXES FOR CONSTANT STREAMFUNCTIONS. INPUT FILE IS ONE LINE .

FIRST LINE INPUT IS N (NUMBER OF NODES DESIRED), NODE1 (STARTING NODE), FV (FLUX VALUE), J (-1 IF NODE # DECREASING, +1 IF INCREASING)

4.5 INCIDENZ.EXE

INCIDENZ.EXE GENERATES THE FINITE ELEMENT NUMBERS AND INCIDENCES FOR TRIANGULAR OR RECTANGULAR ELEMENTS. IN THE INPUT FILE, IN THE FIRST LINE, ENTER THE NUMBER OF COLUMNS OF NODES TIMES TWO . IN THE SECOND LINE ENTER THE NUMBER OF NODES IN THE FIRST COLUMN. IN THE OTHER LINES PUT THE INCIDENCES FOR THE FIRST ELEMENT OF EACH ROW OF THE GRID. NO COUNTER OR ELEMENT NUMBER REQUIRED. PASTE IN THE OUTPUT FILE WITH THE OTHER INPUT DATA.

FOR SQUARE ELEMENTS ,IN THE FIRST LINE, ENTER THE REAL NUMBER OF COLUMNS AND IN THE SECOND LINE ENTER THE REAL NUMBER OF ROWS. IN THE THIRD LINE ENTER THE INCIDENCES FOR THE FIRST ELEMENT.

4.6 NUMBER.EXE

NUMBER.EXE IS USED WHEN A COUNTER IS NECESSARY BEFORE A NODE VALUE. NUMBER.EXE READS A 2 COLUMN DATAFILE AND NUMBERS EACH LINE. THE INPUT FILE CONSISTS ONLY OF THE TWO COLUMN DATAFILE THAT NEEDS TO BE NUMBERED.

IF IT IS NECESSARY TO REVERSE THE ORDER OF THE NUMBERING OF THE NODES,THE "NUMERIC SORT" FEATURE OF WORDPERFECT CAN BE USED.

4.7 SELECT.EXE

SELECT.EXE READS A DATAFILE OF N LINES AND TRANSFERS THE FIRST 5 COLUMNS TO A NEW DATAFILE. THIS IS USEFUL WHEN ONLY PORTIONS OF THE LISTING FILE ARE DESIRED, AS FOR EXAMPLE THE ELEMENT INCIDENCES.

FIRST LINE = N (NUMBER OF LINES TO BE READ)
REST = LINES CONTAINING DESIRED INFORMATION. THESE LINES HAD BEEN "BLOCKED OUT" IN THE APPROPRIATE LISTING FILE AND APPENDED TO THIS INPUT FILE.

4.8 SUBDUBLE.EXE

SUBDUBLE.EXE DOES THE SAME AS SUBTRACT.EXE ,IE. SUBTRACTS A CONSTANT FROM THE WATERTABLE ELEVATION SO THAT THE HEADS ARE IN THE FORM REQUIRED BY THE AUTOMATIC METHOD, IE " HEIGHT OF WATERTABLE

ABOVE YL" ,BUT IT ALSO DOUBLES THE # OF NODES IN THE WATERTABLE BOUNDARY. THIS CAN BE USEFUL IF YOU WANT TO DECREASE THE ASPECT RATIO FOR GRID SIZE SENSITIVITY.

SUBDUBLE.EXE READS A 2 COLUMN DATAFILE (NODE AND WATERTABLE HEAD VALUE) N LINES LONG AND SUBTRACTS S FROM THE 2ND TERM AND PRINTS A COUNTER AND NEW VALUE TWICE.
FIRST LINE= N
SECOND LINE = S
REST= NODE NUMBER AND VALUE. THIS PART WOULD BE PASTED IN FROM AN EXISTING FILE

4.9 SUBTRACT.EXE

SUBTRACT.EXE READS A 2 COLUMN DATAFILE, N LINES LONG AND SUBTRACTS A CONSTANT,S, FROM THE 2ND TERM AND PRINTS A COUNTER AND THE NEW VALUE. IT CAN BE USED TO PREPARE THE WATERTABLE INPUT FILE WHICH REQUIRES SUBTRACTION OF A CONSTANT FROM THE HEAD ELEVATION TO GET THE HEADS IN THE FORM " HEIGHT OF WATERTABLE ABOVE YL".
FIRST LINE= N (NUMBER OF WATERTABLE NODES)
SECOND LINE = S (CONSTANT TO BE SUBTRACTED FROM WATERTABLE VALUE)
REST = NODE AND WATERTABLE HEAD . THIS PART CAN BE PASTED IN FROM AN EXISTING FILE.

5. HOW TO USE TRIPLOT

TRIPLOT, in conjunction with the plotter, is used to plot the contoured results of either the potential or streamfunction versions of FLONET. Keeping in mind the following points ,the documentation for TRIPLOT in the original software is sufficient to guide the user of the program.

TRIPLOT requires a plot information file in addition to the mesh and output files from the FLONET runs. As with any other new file, time can be saved by making a copy of an existing .inf file and using it as a template to which you add pertinent data. The following .inf file (Min.inf) allows a plot of either the grid or the contoured output to be produced in minimum time so that it can be quickly checked for errors. There is no need to change any of the values except the MAX and MIN Y values for the Y-axis. The Max value is the max . elevation , the MIN value is always Zero even though the minimum value on the Y- axis is not .

It is recommended that the grid be plotted first using the grid plot option of TRIPLOT, not only to check that the grid looks like it should, but also so that node and element numbering can be put on a good copy of the grid.

```
Min .inf
   10                                  ;PLOTTER SPEED
       4.0        2.5                  ;X- & Y-MARGINS (CM)
      20.0                             ;LENGTH OF PLOT (CM)
      18.0        0.0                  ;MAX & MIN Y-VALUES FOR Y-AXIS
       1.5                             ;LENGTH OF TICK MARKS (MM)
       2.0        2.0                  ;HEIGHT OF NUMBERS ON X- & Y-AXES
                               (MM)
       3.0        3.0                  ;HEIGHT OF X- & Y-AXIS LABELS (MM)
    2    2                             ;NUMBER OF TICKS ALONG X- & Y-AXES
X                                                          ;XLABEL
Z                                                          ; YLABEL
1                                      ;NUMBERS ALONG X-AXIS STARTING AT
                                       LEFT
1
1                                       ;NUMBERS ALONG Y-AXIS STARTING AT
                                        BOTTOM
1
```

When viewing the plot, check that the plot makes sense, ie, should the equipotentials get closer together as you move downgradient?

The velocity plot feature for the modified version of TRIPLOT is not working at the present time. This is being pursued.

6. MISCELLANEOUS COMMENTS

1. For the initial runs of a FLONET problem, have the listing file echo the input data. This enables it to be checked to ensure that the input data are correct.

2. The mass balance in the FLONT32 listing file is not a full mass balance in that it only considers the specified head and not the specified flux nodes. If the mass balance is checked by using ADD.EXE, it will generate the same values as the listing file for the total mass in and mass out of the domain but not the same individual node values. The reason for this is not evident at this time.

3. If a problem is too big for the computer to fit onto one grid, it can be split into parts and each part modelled separately. For example , in the domain depicted in Fig 6, the flux entering the domain along the top boundary (determined by using ADD.EXE) can be used as input for the bottom boundary of another domain located on top. In this way the two domains have a common boundary and are therefore linked.

4. If the code fails to run and throws you back to DOS, try trouble shooting your problem by running the version of FLONET called TRACE.EXE. TRACE.EXE echos to the screen what the code is doing and therefore the last comment echoed to the screen will be where your error likely starts.

APPENDIX 1

GLOSSARY OF TERMS

ASPECT RATIO	The ratio of the length to the height of the finite element in the grid. Ideally, it should be within a factor of 10, but within a 100 can be allowed. Grid-size sensitivity tests can be run using the autogrid method and can indicate what aspect ratios are possible. See Fig. 1
BANDWIDTH	Effectively equal to the difference between the max and min node number in an element plus 1. See Fig. 1
DARCY FLUX	Volume of water crossing a unit area per unit time [L/T]. This type of flux is necessary for the automatic grid generation method and contrasts with the nodal flux required when the grid is entered manually.
DIRICHLET NODE	Node having specified head
DOMAIN	The modelled area.
FLUX	General term for flow rate per area, (volume/ area/time.[L/T]) where area is either the total area or unit area .

FLUX BOUNDARY	Boundary of domain where flux is specified
HEAD BOUNDARY	Boundary of domain where head is specified
INCIDENCES	The node numbers of the corners of an element. In FLONET the nodes are listed counterclockwize.
K	Hydraulic Conductivity
NEUMAN NODE	Node having specified flux.
NODAL FLUX	Volume of water per time passing through an area composed of unit thickness and a distance of halfway from the previous node to halfway to the next. This type of flux is required when the grid is entered manually.
NN	NUMBER OF NODES IN THE DOMAIN
NE	NUMBER OF ELEMENTS IN THE DOMAIN
NC	TOTAL NUMBER OF DIRICHLET (SPECIFIED HEAD) NODES (INCLUDING NIC) WHERE NIC=NUMBER OF INTERNAL DIRICHLET NODES
NF	TOTAL NUMBER OF NEUMAN NODES (SPECIFIED FLUX) (INCLUDING NIF) WHERE NIF=NUMBER OF INTERNAL NEUMAN

	NODES. NIC AND NIF MUST BE 0 (ZERO) IF STREAMFUNCTION MODE USED.
N	NUMBER OF DEGREES OF FREEDOM OR # OF UNKNOWNS
NB	BANDWIDTH
NH	NUMBER OF NODES IN HORIZONTAL DIRECTION
NIC,NIF	NUMBER OF SPECIFIED HEAD AND FLUX NODES THAT ARE INSIDE THE MODELLED DOMAIN
NV	NUMBER OF NODES IN VERTICAL DIRECTION
REFERENCE STREAMLINE	THAT STREAMLINE WHICH HAS THE MINIMUMFLUX IN THE DOMAIN.
RELAXATION	TERM EXPRESSING A FEATURE OF THE AUTOMATIC METHOD WHEREBY THE TOPOGRAPHY OF THE TOP SURFACE IS ALLOWED TO PROPOGATE THROUGH THE DOMAIN WITHOUT CHANGING THE NUMBER OR RELATIVE POSITION OF THE ELEMENTS
SLOPE	SLOPE OF HYPOTENUSE OF ELEMENT. -1 IS SLOPING FROM UPPER LEFT TO LOWER RIGHT. THE FLOW DIRECTION SHOULD BE ALONG THE HYPOTENUSE RATHER THAN PERPENDICULAR TO IT.
XL	LENGTH OF DOMAIN IN THE X DIRECTION
YL	LENGTH OF LEFT SIDE OF DOMAIN IN THE Y (VERTICAL) DIRECTION

APPENDIX 2

HOW TO USE THE BLOCK, MOVE AND APPEND FEATURES OF WORDPERFECT

Many of the steps described in this guide involve using BLOCK and MOVE or APPEND features of WORDPERFECT. A brief discussion of how to block out a segment of an existing datafile and move the block to another file or a new file follows:

a) move curser to beginning of material to be blocked.
b) press ALT-F4 to activate the BLOCK feature and the down arrow to start blocking.
c) when finished, press CTRL-F4 to MOVE and select 1) ,2) or 3)
d) 1) or 2) allows movement of blocks within the document and requires pressing CTRL-F4 and 5 to restore the moved text.
e) 3) allows appending the blocked material to another file. All that is required is the filename of the destination file and pressing CTRL-F4 and 5 to restore the moved text.

A quick method of appending a whole file to an existing file is to:
- position curser where you want the new material
    - press F5 and list the files that contain the desired file
    - press 1 to retrieve the file

The file will now be in the desired position and can be manipulated in normal ways.